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1

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ATMOSPHERIC MOTION COHERENT PULSE DOPPLER RADAR SYSTEM

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The invention described herein may be manufactured and used by or for the U.S. Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to the measurement of atmospheric motion; and more particularly to the measurement of such motion utilizing pulse Doppler radar.

A conventional method of measuring wind velocity is "Rawin." This method employs balloons. A balloon is released and its movement is tracked with a radar beam as it rises. The horizontal motion of the balloon is then computed by means of the changing horizontal position as indicated by return echos from the balloon. Unfortunately, a great many balloons are needed to indicate periodic changes in wind velocity. Furthermore, the data received is necessarily a mean value, for the balloon rises continuously and at least two consecutive reflections are needed to compute horizontal velocity and the value derived represents the mean between reflections. Another requirement of previous pulsed Doppler wind measuring systems has been the need for more than one radar.

The present invention uses precipitation clouds or "chaff" targets as tracers of the wind. It is further anticipated that discontinuities of temperature and humidity at varying altitudes will be utilized for the same purpose. With an extremely sensitive radar it could be possible to use the present invention in clear air. Atmospheric inhomogeneities due to differences in temperature and humidity will act as a trace of the wind as opposed to the use of precipitation clouds. Motion in the ionosphere can also be determined by utilizing back scatter from ionized layers.

The present invention is very flexible. Practically instantaneous determinations of atmospheric motion can be obtained at will. Such could not be accomplished with conventional means, because determinations are tightly coupled with the motion of balloons. Twelve levels one thousand feet apart have been sampled in two minutes within a five-mile radius with the present invention. On the other hand, aforesaid conventional means required twelve minutes with a mean wind velocity of fifty miles per hour over a ten-mile area. Obviously as wind velocity increases, the mean velocity would necessarily spread over a much larger area. In this respect, the present invention is independent of wind velocity.

The accuracy of conventional wind velocity measurements is on the order of ± 1 to ± 1.5 meters per second. Doppler measurements have provided an accuracy of ± 0.5 meters per second with equipment of average quality utilizing this method.

In addition to the ability of the present invention to provide an improved method for determining horizontal motion, it can also be utilized in determining the fall velocity of moisture particles, turbulence and the magnitude and direction of the wind shear vector acting upon a given sampled layer.

Precipitation particles have two components of velocity acting upon each particle, a horizontal component related to wind velocity and a vertical component related to vertical fall. Such vectors are depicted in FIG. 1. Cloud velocity can be regarded as a special case of the above, wherein vertical fall velocity of the particle is approximately zero. Vertical fall varies considerably with different particles. For snow, the range is from 0.3 to 2 meters per second; for rain, the range is from 4 to 9 meters per second.

2

The reflections from a preselected altitude are not confined to a point but more properly to a cube in space. As will be demonstrated more fully, this principle gives rise to the principle that reflected Doppler signals contain a spectrum of frequencies. This spectrum is broadened by several factors; variations in vertical fall velocities, the finite width of the radar beam, turbulence of a small scale contained within the sampled volume, and wind shear. Normal variations in vertical fall and the finite width of the radar beam produce negligible broadening. Turbulence of a small scale having a variety of random directions produce noise-like oscillations that are readily distinguished from broadening produced from other causes. Wind shear produces definite broadening. Considering the foregoing and other features that will be more fully discussed, wind shear and turbulence can be determined as well as horizontal motion.

In view of the foregoing, an object of this invention is to provide a flexible method for determining atmospheric motion.

Another object of this invention is to determine atmospheric motion with greater accuracy than has been hitherto achieved with conventional methods.

Another object of this invention is to determine atmospheric motion with the use of only one radar.

Another object of this invention is to provide a measure of wind shear and turbulence in addition to wind velocity.

Other objects and advantages will best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1, a pictorial view of radar scanning the atmosphere.

FIG. 2, a sectional view of FIG. 1.

FIG. 3, a block diagram of an embodiment of this invention.

FIG. 4, a block diagram of a second embodiment of this invention.

FIG. 5, a distribution of the frequencies in connection with the subtraction network of FIG. 4.

FIG. 6, a comparative display of scans taking various harmonics.

FIG. 7, a display illustrating its component parts; and

FIG. 8, several displays illustrating various effects due to differing atmospheric conditions.

A pulse Doppler radar is used to radiate and receive signals. A "C" band pulse Doppler radar called "porcupine" having a P.R.F. of 10 kc., a conical beam of 2°, peak power of 16 kw., and 0.8 μsec. pulse width worked satisfactorily. Reflected signals represent the power density of water droplets having a radial velocity.

With the beam tilted at elevation **17**, FIG. 1, the velocity of the particles will be represented by:

$$V = V_2 \sin \alpha + V_1 \cos \alpha \cos \beta$$

wherein

α=the angle of elevation
$\beta(2)$=the azimuth angle relative to wind direction
V_f14=vertical fall velocity
V_h13=horizontal wind velocity

This equation is represented vectorially in FIG. 1.

By rotating the azimuth in a P.P.I. scan (angle α–**17** and Range-R, held constant, V–**15** will vary with β–**24** as is shown in FIG. 7 at an altitude of $R \sin \alpha$.

It will be observed in FIG. 7 that curve of velocity V vs. angle β, **83**, has two maxima, wherein

$$V = V_h \cos \alpha + V_f \sin \alpha$$

and $V = V_h \cos \alpha - V_f \sin \alpha$, respectively. Curve **83** has